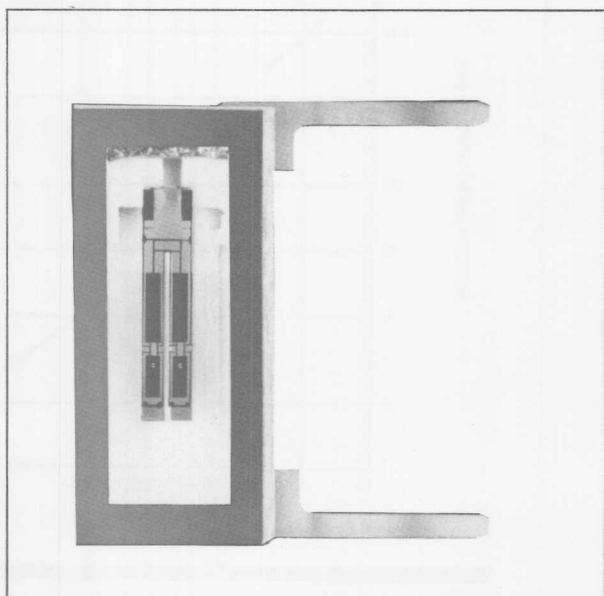




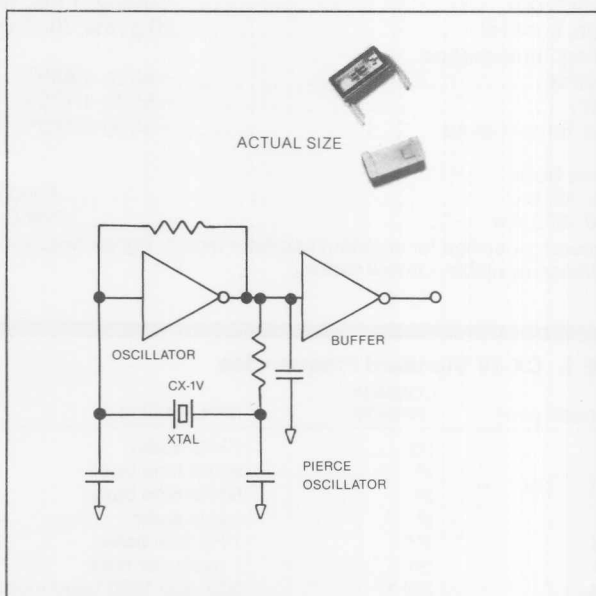
Miniature Quartz Crystals

Low Frequency (10–600 kHz)
MODEL CX-1V
For Pierce Oscillators



Features

- Miniature tuning fork design
- High shock resistance
- Excellent aging characteristics
- Designed for low power applications
- Compatible with hybrid or PC board packaging
- 10 kHz to 600 kHz frequency range
- Full military testing available



Description

The Model CX-1V quartz crystal is a high quality tuning fork resonator intended for use in Pierce (single inverter) oscillators. The CX-1V frequency range of 10 kHz to 600 kHz is available in a rugged, miniature ceramic package, one-fourth the size of an eight-pin mini-DIP. The CX-1V crystal is manufactured by a Statek-developed photolithographic process, and was designed utilizing the experience acquired in producing millions of crystals for industrial, consumer and military applications.



Specifications

Specifications are typical at 25°C unless otherwise noted. Specifications subject to change without notice.

Frequency (see Table 1) ¹	10 to 600 kHz
Frequency Calibration ² (see Tables 2 and 3) .. A, B, or C Tolerance	
Motional Resistance, R_1	Figure 2 (Maximum: 10–169 kHz, 2x typical; 170–600 kHz, 2.5x typical)
Motional Capacitance, C_1	Figure 3
Quality Factor, Q	Figure 4 (Minimum is 0.25 x typical)
Shunt Capacitance, C_0	1.4 pf typical
Drive Level	10–25 kHz 0.5 μ W maximum 25–600 kHz 1.0 μ W maximum
Turning Point, T_0	Figure 5
Temperature Coefficient, k	–0.035 ppm/°C ²
Aging, first year	5 ppm maximum
Shock, survival	1,000 g, 1 ms, ½ sine
Vibration, survival	20 g rms, 10–2,000 Hz
Operating Temperature	
Industrial	–40 to +85°C
Military	–55 to +125°C
Storage Temperature	–55 to +125°C

1. Flexure Mode
10–169 kHz Fundamental
170–600 kHz First Overtone
2. Frequency specified for standard oscillator circuit. Tighter frequency calibration available; consult factory.

TABLE 1. CX-1V Standard Frequencies

FREQUENCY (kHz)	COMMON DIVISION	APPLICATION
10	10	1 kHz audio
12.8	2 ⁸	50 Hz time base
15.36	2 ⁸	60 Hz time base
16	2 ⁴	1 kHz audio
16.384	2 ¹⁴	1 Hz time base
18.641	2 ²⁶	1 cycle per hour
19.2	2 ^{6,5,4}	300, 600, 1200 baud modem
20.48	2 ¹²	5 Hz clock motor
25	—	Ultrasonic alarm transducer
30.72	2 ⁹	60 Hz time base
31.5	—	T.V. raster
32.768	2 ¹⁵	1 second time base
38.4	2 ^{6,5,4}	600, 1200, 2400 baud modem
40	—	Ultrasonic alarm transducer
40.96	2 ¹²	10 Hz clock motor
60	—	WWVB PLL
76.8	2 ^{6,5,4}	1200, 2400, 4800 baud modem
100	—	Calibrator
153.6	2 ^{6,5,4}	2400, 4800, 9600 baud modem
240	2 ⁷	Motor control
307.2	2 ^{7,6,5}	2400, 4800, 9600 baud modem
500	—	Microprocessor

TABLE 2. CX-1V Crystal Calibration Tolerances at 25°C

Calibration	10–74.9	75–169	170–249	250–600 kHz
A	±0.003%	±0.005%	±0.01%	±0.02%
B	±0.01%	±0.01%	±0.02%	±0.05%
C	±0.1%	±0.1%	±0.2%	±0.5%

FIGURE 1. Equivalent Circuit

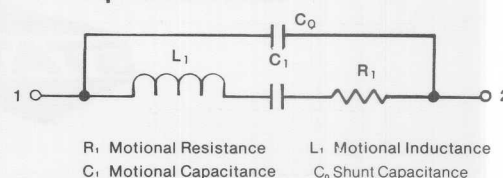


FIGURE 2. CX-1V Typical Motional Resistance, R_1

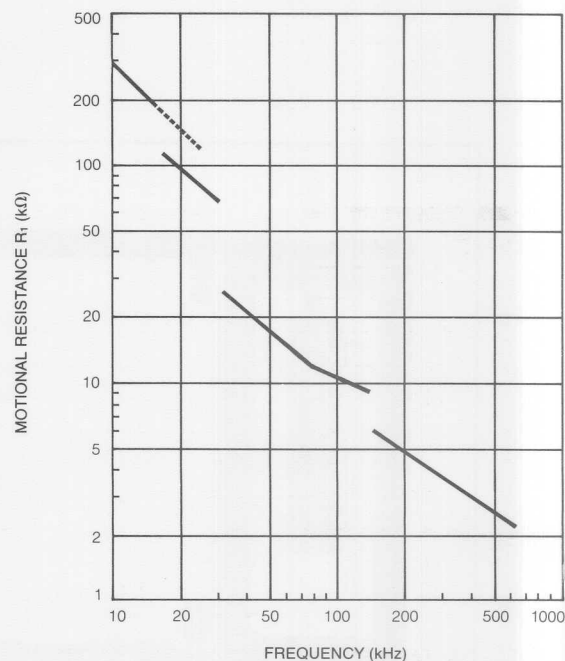


FIGURE 3. CX-1V Typical Motional Capacitance, C_1

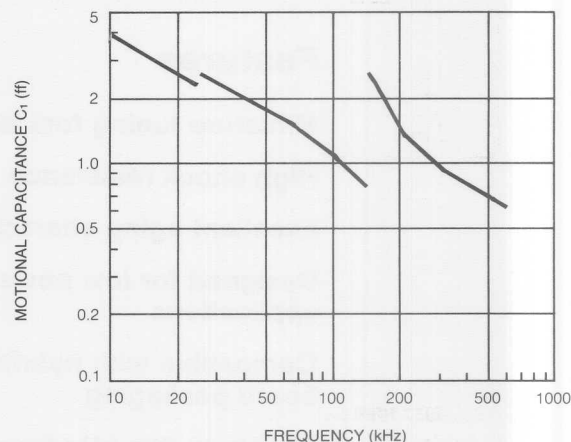


TABLE 3. Load Capacitance, C_L , Used to Calibrate CX-1V Crystals

FREQUENCY RANGE (kHz)	LOAD CAPACITANCE (pf)	FREQUENCY RANGE (kHz)	LOAD CAPACITANCE (pf)
10-15.99	11	55-100	8
16-24.99	10	100.1-179.9	5
25-54.99	9	180-600	4

FIGURE 4. CX-1V Typical Quality Factor, Q

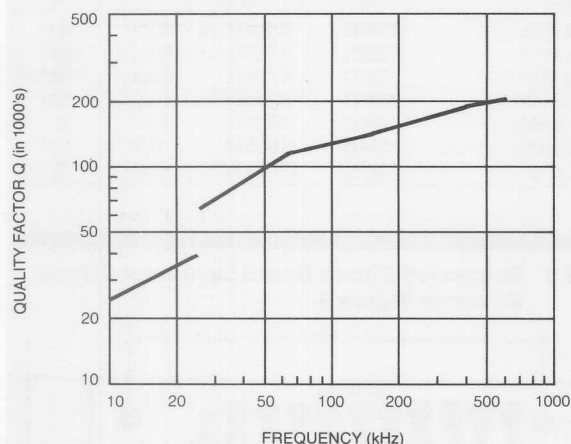


FIGURE 5. CX-1V Typical Turning Point Temperature

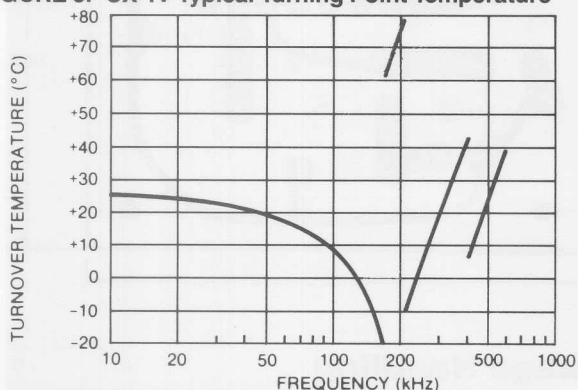


FIGURE 6. CX-1V Package Dimensions

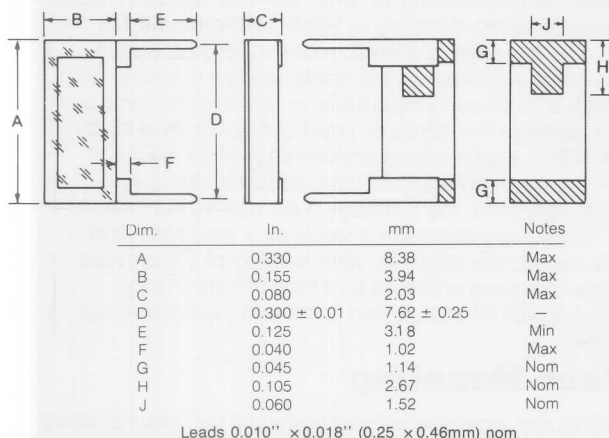
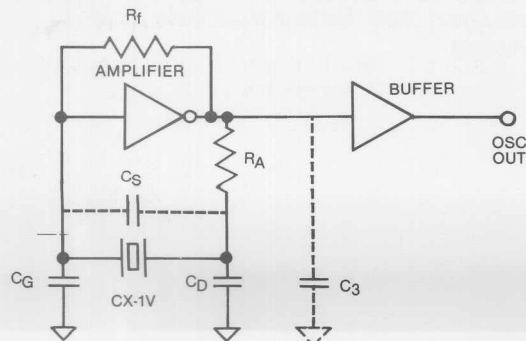


FIGURE 7. Conventional CMOS Pierce Oscillator



Applications

The CX-1V is designed for applications requiring small size, ruggedness, high stability, and lowest possible current. The CX-1V is ideal for such diverse battery-powered applications as time-of-day clocks, instrumentation time bases, portable terminals, calculators, watches, voice scramblers, pagers, and hand-held radios. The CX-1V is designed for use in Pierce (single inverter) oscillators.

Crystal Oscillator Characteristics

Circuit Design Considerations

The conventional CMOS Pierce oscillator is shown in Figure 7. The crystal oscillates at a frequency, f_o , 15 to 150 ppm above the crystal's series resonant frequency, f_s . The crystal is effectively inductive and in combination with C_D and C_G in the feedback loop provides approximately 180° phase shift necessary to sustain oscillation.

Removal of the crystal from the circuit will generally cause the oscillator to stop. Capacitor C_3 is required for some I.C.'s and in some high voltage applications (at operating frequencies below 170 kHz) to prevent operation in the crystal's overtone mode. This is accomplished by limiting the amplifier's bandwidth. C_3 can vary from 50 to 1000 pf. Note that crystals 170 kHz and above operate in the first overtone (approximately six times fundamental).

Feedback Resistance

The feedback resistor R_f sets the bias point for the amplifier in the linear region. R_f should be large enough so as not to appreciably affect the phase of the feedback network. A typical value for R_f is 22 MΩ. Reducing this value will lower loop gain and widen the amplifier bandwidth.

Drive Level

Resistor R_A is used to limit the crystal's drive level by forming a voltage divider between R_A and C_D . R_A also stabilizes the oscillator against changes in R_o , the output impedance of the amplifier. R_A should be increased for higher voltage operation.

Drain Capacitor (C_D)

Capacitor C_D provides phase shift and reduces crystal drive. Typical values for C_D range from 5 to 40 pf. Large values of C_D tend to stabilize the oscillator against variations in power supply voltage. Large values also reduce the tuning capability of the oscillator and overtone activity.

Gate Capacitor (C_G)

Capacitor C_G provides phase shift and input voltage for the amplifier. In most oscillator circuits C_G is used to adjust the oscillator to frequency. Typical values for C_G range from 0 to 20 pf. Large values reduce loop gain and increase stability.

Circuit Board Layout

Because of the low motional capacitance associated with small crystals and the high impedances associated with low power oscillators, the oscillator designer must be concerned with circuit layout. Stray capacitance (C_S) should be kept below 1 pf for best oscillator performance. Circuit board traces should be kept to a maximum of one inch (2.54 cm) and there should be no parallel traces. Large values of stray capacitance reduce loop gain and stability.

Load Capacitance (C_L)

The CX-1V frequency calibration is based on a load capacitance, C_L , as depicted in Table 3. C_L is defined as the capacitance which, when added in series with the crystal in an impedance meter, will produce the frequency of operation in the intended oscillator circuit. C_L is related to C_D , C_G and C_S in Figure 7 approximately as follows:

$$C_L \approx \frac{C_D \times C_G}{C_D + C_G} + C_S$$

NOTE: C_D and C_G include stray layout and other circuit capacitances. In practice the effective value of C_L will be less than that calculated from C_D , C_G and C_S values because of the effect of the amplifier output impedance.

Popular Pierce Oscillator Application

The circuit in Figure 8 is a popular design that will satisfy most applications. Typical component values and recommended circuit board layout are given in Table 4 and Figure 9.

FIGURE 8. Popular Pierce Oscillator Using CD4060 Oscillator/Divider

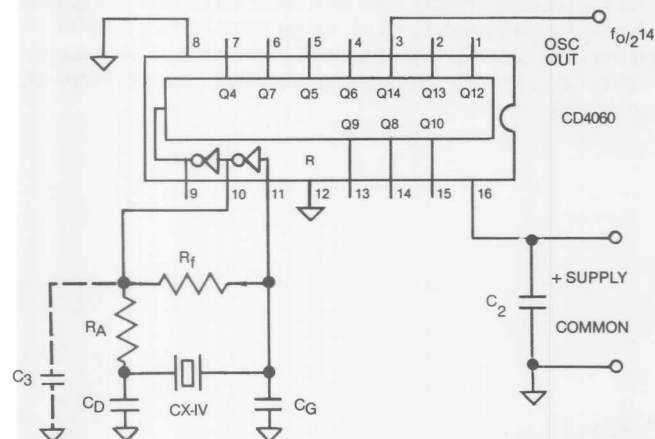
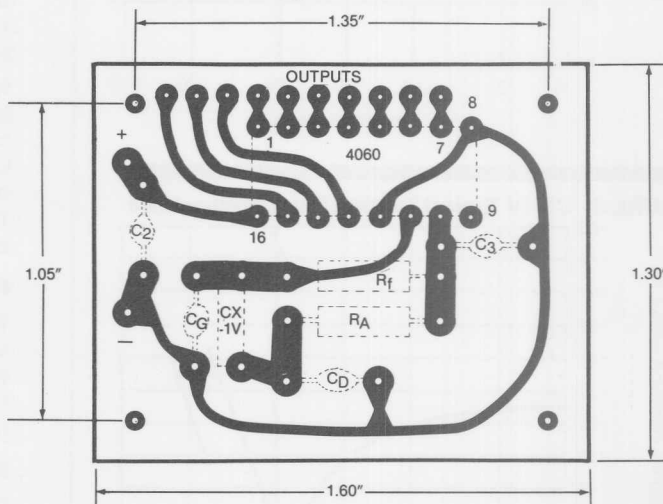


TABLE 4. Initial Component Values for Designing Pierce Oscillator (Figure 8) at 5 VDC

FREQUENCY	R_f	R_A	C_D	C_G
10–15.9 kHz	22M Ω	680k Ω	33pf	20pf
16–24.9 kHz	22M Ω	470k Ω	33pf	10pf
25–54.9 kHz	22M Ω	470k Ω	20pf	10pf
55–129.0 kHz	22M Ω	330k Ω	10pf	5pf
130–199.9 kHz	22M Ω	220k Ω	10pf	0
200–349.9 kHz	10M Ω	150k Ω	5pf	5pf
350–600 kHz	10M Ω	100k Ω	5pf	0

FIGURE 9. Suggested Circuit Board Layout for Circuit Shown in Figure 8.



Package Handling

The CX crystal is hermetically sealed in a ceramic package with a soft soldered glass lid and leads. Normal handling and soldering precautions for small low thermal mass parts are adequate when installing or testing CX crystals. CX crystals may be wave soldered, with proper precaution taken to avoid desoldering the leads. A slow machine rate or too high a pre-heat temperature or solder bath temperature can damage the crystals. Lead temperature should not exceed 175°C, seal rim temperature should not exceed 210°C. If the seal rim reaches temperatures above the maximum specified, the package may lose its hermeticity. Loss of hermeticity results in a frequency decrease and motional resistance increase. Mishandling of CX crystals can cause cracking of the lid and loss of hermeticity. Excessive shock of unmounted parts can cause damage to the crystal.

Surface Mounting

CX crystals are available without leads for surface mounting on hybrid circuits or printed circuit boards. Seal rim temperature should not exceed 210°C for standard products. For high-temperature surface-mounting processes, refer to Statek data sheet titled "Surface Mountable Miniature Quartz Crystals."

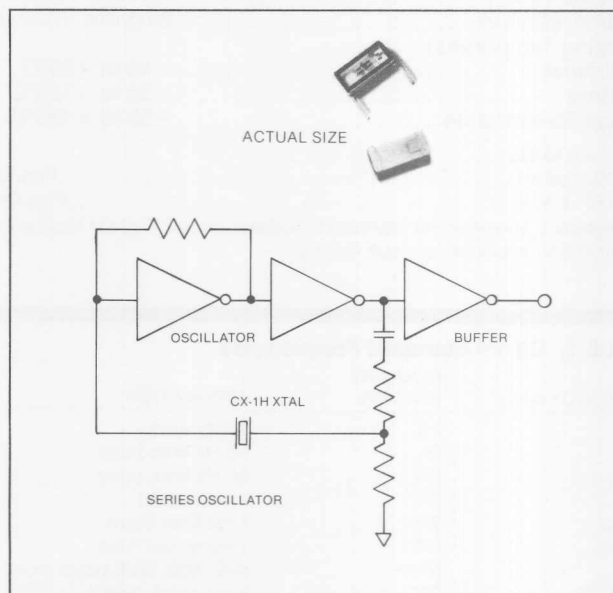
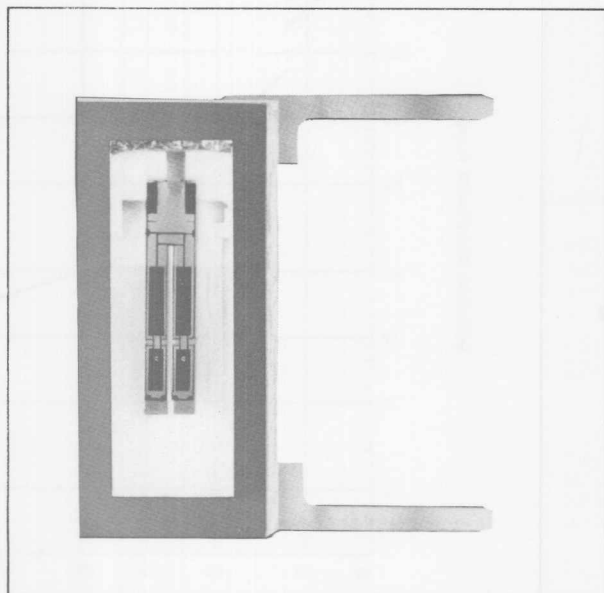


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Miniature Quartz Crystals

Low Frequency (10–600 kHz)
MODEL CX-1H
For Series Oscillators



Features

- Miniature tuning fork design
- High shock resistance
- Excellent aging characteristics
- Compatible with hybrid or PC board packaging
- 10 kHz to 600 kHz frequency range
- Full military testing available

Description

The Model CX-1H quartz crystal is a high quality, tuning fork resonator intended for use in series (two cascaded inverters) oscillators. The CX-1H frequency range of 10 kHz to 600 kHz is available in a rugged, miniature ceramic package, one-fourth the size of an eight-pin mini-DIP. The CX-1H crystal is manufactured by a Statek-developed photolithographic process, and was designed utilizing the experience acquired in producing millions of crystals for industrial, consumer and military applications.



Specifications

Specifications are typical at 25°C unless otherwise noted. Specifications subject to change without notice.

Frequency (see Table 1) ¹	10 to 600 kHz
Frequency Calibration ² (see Table 2)	A, B, or C Tolerance
Motional Resistance, R_1	Figure 2 (Maximum: 10–169 kHz, 2x typical; 170–600 kHz, 2.5x typical)
Motional Capacitance, C_1	Figure 3
Quality Factor, Q	Figure 4 (Minimum is 0.25 x typical)
Shunt Capacitance, C_0	1.4 pF typical
Drive Level	10–25 kHz 1.5 μ W maximum 25–600 kHz 3.0 μ W maximum
Turning Point, T_0	Figure 5
Temperature Coefficient, k	–0.035 ppm/°C ²
Aging, first year	5 ppm maximum
Shock, survival	1,000 g, 1 ms, ½ sine
Vibration, survival	20 g rms, 10–2,000 Hz
Operating Temperature	
Industrial	–40 to +85°C
Military	–55 to +125°C
Storage Temperature	–55 to +125°C

1. Flexure Mode
10–169 kHz Fundamental
170–600 kHz First Overtone
2. Frequency specified for standard oscillator circuit. Tighter frequency calibration available; consult factory.

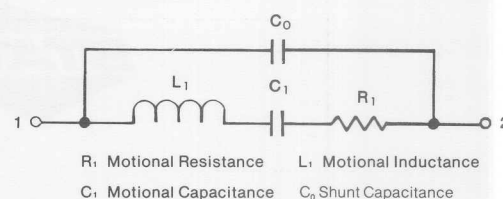
TABLE 1. CX-1H Standard Frequencies

FREQUENCY (kHz)	COMMON DIVISION	APPLICATION
10	10	1 kHz audio
12.8	2 ⁸	50 Hz time base
15.36	2 ⁸	60 Hz time base
16	2 ⁴	1 kHz audio
16.384	2 ¹⁴	1 Hz time base
18.641	2 ²⁶	1 cycle per hour
19.2	2 ^{6,5,4}	300, 600, 1200 baud modem
20.48	2 ¹²	5 Hz clock motor
25	—	Ultrasonic alarm transducer
30.72	2 ⁹	60 Hz time base
31.5	—	T.V. raster
32.768	2 ¹⁵	1 second time base
38.4	2 ^{6,5,4}	600, 1200, 2400 baud modem
40	—	Ultrasonic alarm transducer
40.96	2 ¹²	10 Hz clock motor
60	—	WWVB PLL
76.8	2 ^{6,5,4}	1200, 2400, 4800 baud modem
100	—	Calibrator
153.6	2 ^{6,5,4}	2400, 4800, 9600 baud modem
240	2 ⁷	Motor control
307.2	2 ^{7,6,5}	2400, 4800, 9600 baud modem
500	—	Microprocessor

TABLE 2. CX-1H Crystal Calibration Tolerances at 25°C

Calibration	10–74.9	75–169	170–249	250–600 kHz
A	±0.003%	±0.005%	±0.01%	±0.02%
B	±0.01%	±0.01%	±0.02%	±0.05%
C	±0.1%	±0.1%	±0.2%	±0.5%

FIGURE 1. Equivalent Circuit



R_1 : Motional Resistance L_1 : Motional Inductance
 C_1 : Motional Capacitance C_0 : Shunt Capacitance

FIGURE 2. CX-1H Typical Motional Resistance, R_1

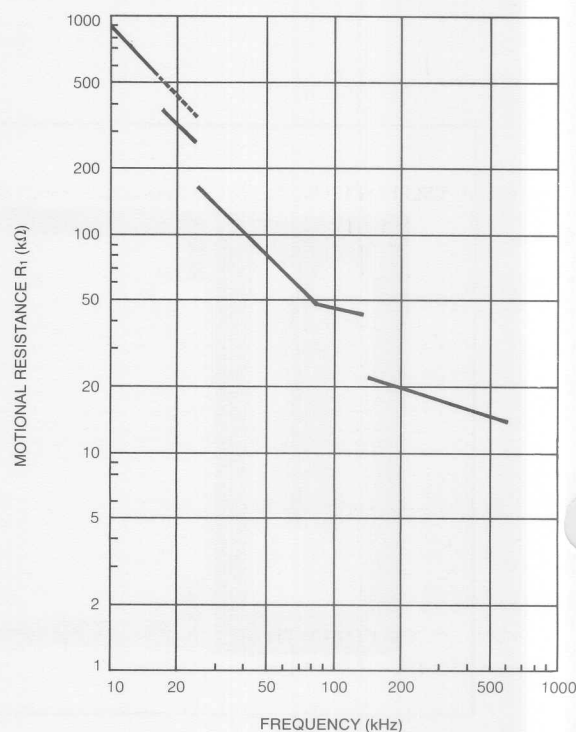


FIGURE 3. CX-1H Typical Motional Capacitance, C_1

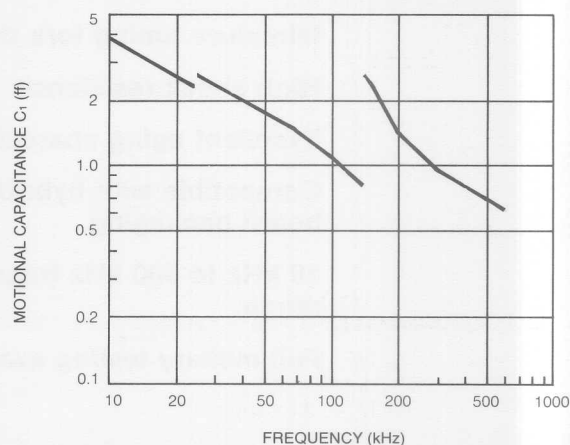


FIGURE 4. CX-1H Typical Quality Factor, Q

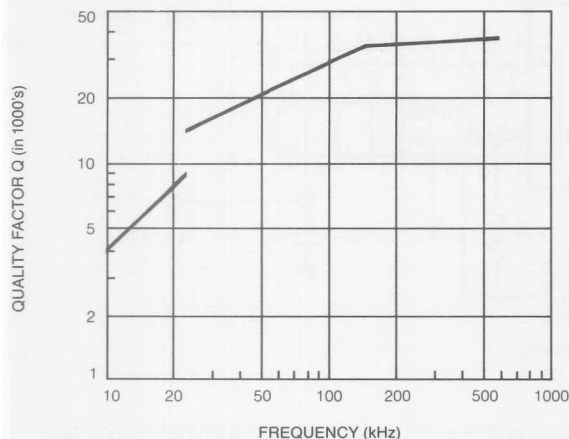


FIGURE 5. CX-1H Typical Turning Point Temperature

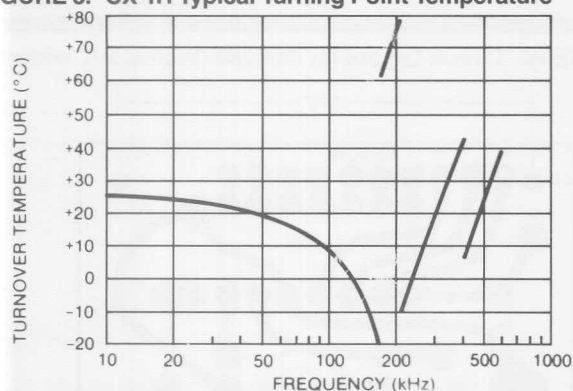


FIGURE 6. CX-1H Package Dimensions

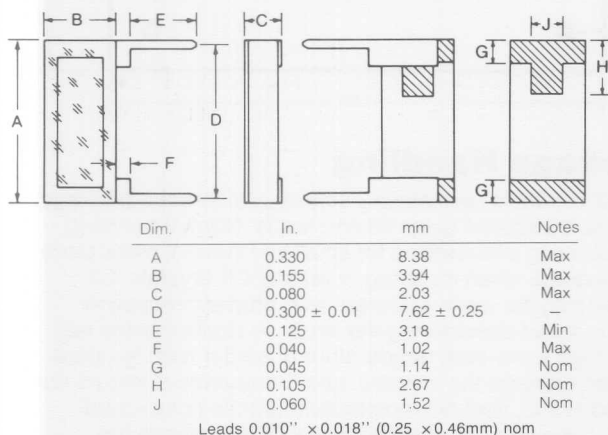
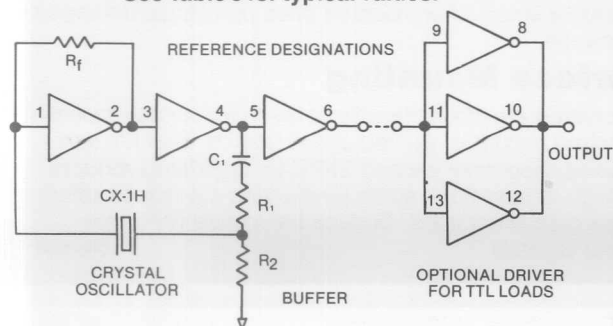


FIGURE 7. Typical Application as Series Oscillator CMOS HEX Inverter CD4069 at 5 VDC. See Table 3 for typical values.



Circuit Design & Layout Considerations

The CX-1H crystal is designed for applications requiring rapid start-up, small size, ruggedness, high reliability, and long storage. The CX-1H crystal in a series oscillator is ideally suited for low cost, high volume applications.

Series oscillators are usually designed using two cascaded inverters, as shown in Figure 7. The crystal oscillates at a frequency, f_o , 10 to 100 ppm below the series resonant frequency, f_s , of the crystal. The higher the Q (higher frequency) the closer the crystal will run to series resonance, f_s . The reactance of the crystal is capacitive in a series oscillator. Circuit layout capacitance across the crystal provides a low Q feedback which degrades oscillator performance. The basic series oscillator is shown in figure 7. Table 3 gives typical values which are used in the oscillators used to tune CX-1H crystals.

TABLE 3. Initial Component Values for Designing a Series Oscillator at 5 VDC

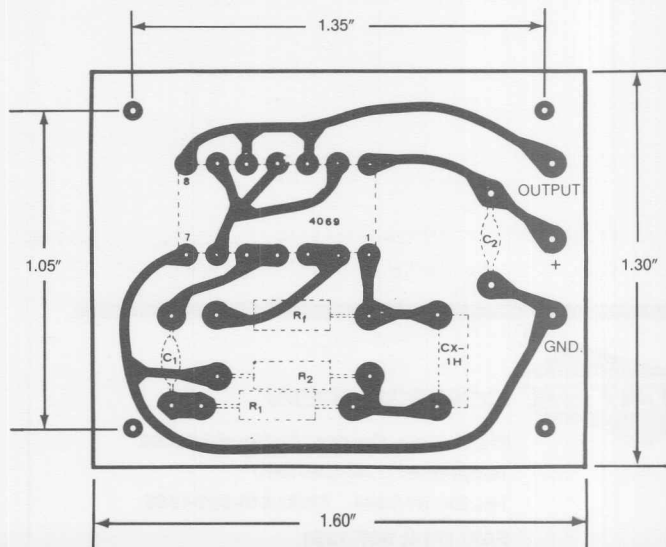
FREQUENCY	R_f	R_1	R_2	C_1
10–15.9 kHz	5M Ω	470k Ω	470k Ω	—
16–24.9 kHz	3M Ω	470k Ω	470k Ω	—
25–39.9 kHz	2M Ω	220k Ω	220k Ω	—
40–64.9 kHz	1M Ω	220k Ω	220k Ω	—
65–119.9 kHz	470k Ω	220k Ω	220k Ω	—
120–199.9 kHz	470k Ω	27k Ω	27k Ω	30pf
200–249.9 kHz	470k Ω	27k Ω	27k Ω	10pf
250–349.9 kHz	220k Ω	27k Ω	27k Ω	10pf
350–600 kHz	120k Ω	27k Ω	27k Ω	5pf

NOTE: C_2 (Figure 8) is circuit board power supply decoupling. 0.1 μ f is usually adequate.

Circuit Board Layout

Because of the low motional capacitance associated with small crystals and the high impedances associated with low power oscillators, the oscillator designer must be concerned with circuit layout. Stray capacitance should be kept below 1 pf for best oscillator performance. Circuit board traces should be kept to a maximum of 1 inch (2.54 cm), and there should be no parallel traces. Large values of stray capacitance reduce loop gain and stability.

FIGURE 8. Layout Series Oscillator for Using CD4069 HEX Inverter



Oscillator design is most conveniently done with a breadboard which closely approximates final circuit layout. Do not use large patch-wire type sockets.

Computer modeling and theoretical designs will usually be affected by the physical implementation of the circuit. Theoretical circuit calculations will be accurate if the layout capacitance of each node is known and tallied. Usually this information is unknown and difficult to measure. The simplest procedure is to measure the oscillator supply current, frequency of operation, start time and waveform—and observe their change during tests and component changes.

Feedback Resistance

The feedback resistor, R_f , may typically range from $100k\Omega$ to $10M\Omega$. An indication of amplifier bandwidth and circuit shunt capacitance may be obtained by measuring the oscillator free run frequency. The oscillator will usually oscillate without the crystal due to normal stray capacitance. The higher the frequency, the lower the shunt capacitance and the wider the amplifier bandwidth. The feedback resistor value should be adjusted for a free run frequency of about 1.5–2 times the crystal frequency. This insures adequate bandwidth for oscillation of the crystal fundamental frequency, and roll-off to minimum gain at the first overtone.

Note: crystals 170 kHz and above operate in first overtone (approximately 6 times fundamental).

The circuit phase lead capacitor, C_1 aids in operating the crystal at the correct frequency. C_1 also provides D.C. isolation for current to ground through R_1 and R_2 , and increases bandwidth which is necessary at the higher frequencies. This reduces oscillator current. Typical values for C_1 range from 5 to 30 pf.

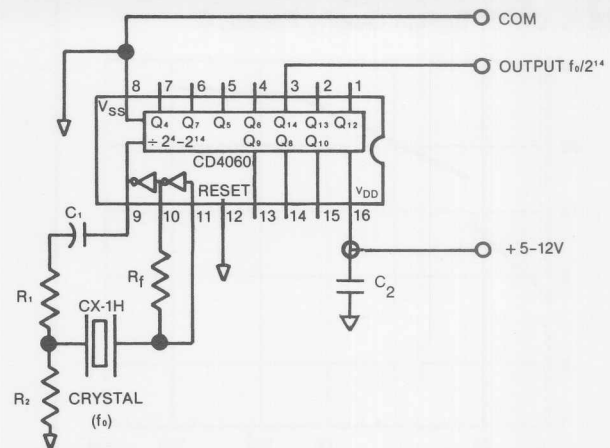
Drive Level

Resistors, R_1 and R_2 aid in producing a phase lead in conjunction with C_1 , and also reduce crystal drive voltage. The values in Table 3 show equal values for half drive level for a five volt supply. Note: Approximately one-fifth drive level is recommended at 12 volts.

Low-Cost Oscillator Application

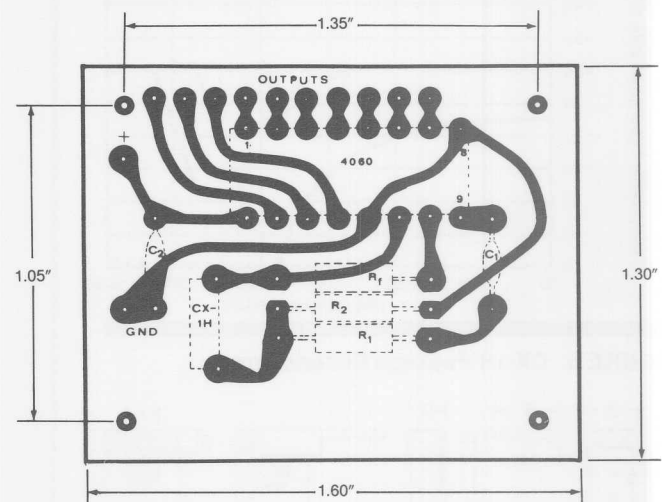
A low cost crystal controlled oscillator, with four to 14 stages of binary division, may be built using a single I.C., a CX-1H crystal, and one to four additional components. A 16.384 kHz crystal may be divided by 2^{14} (14 stages of binary division) to produce a one Hz output using the circuit shown in Figure 9. Component values are as previously described. Use Table 3 values for initial tests.

FIGURE 9. Low Cost CD4060 Oscillator/Divider Circuit



The circuit is drawn to imply a physical layout of components to minimize stray capacitance across the crystal. Figure 10 shows circuit board layout.

FIGURE 10. Circuit Layout for CD4060 Oscillator/Divider



Package Handling

The CX crystal is hermetically sealed in a ceramic package with a soft soldered glass lid and leads. Normal handling and soldering precautions for small low thermal mass parts are adequate when installing or testing CX crystals. CX crystals may be wave soldered, with proper precaution taken to avoid desoldering the leads. A slow machine rate or too high a pre-heat temperature or solder bath temperature can damage the crystals. Lead temperature should not exceed 175°C, seal rim temperature should not exceed 210°C. If the seal rim reaches temperatures above the maximum specified, the package may lose its hermeticity. Loss of hermeticity results in a frequency decrease and motional resistance increase. Mishandling of CX crystals can cause cracking of the lid and loss of hermeticity. Excessive shock of unmounted parts can cause damage to the crystal.

Surface Mounting

CX crystals are available without leads for surface mounting on hybrid circuits or printed circuit boards. Seal rim temperature should not exceed 210°C for standard products. For high-temperature surface-mounting processes refer to Statek data sheet titled "Surface Mountable Miniature Quartz Crystals."

C1H-10/87



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